

## Method and system of retransmission

### TECHNICAL FIELD OF THE INVENTION

The present invention relates to retransmissions in a communications system, and more especially it relates to a  
5 cellular mobile radio system, particularly to a Universal Mobile Telecommunications System, UMTS or WCDMA system.

### BACKGROUND AND DESCRIPTION OF RELATED ART

Retransmission of data to or from a mobile station, MS, or user equipment, UE, is previously known. It is also known  
10 to use medium access control and radio link control layers of a UMTS protocol structure in acknowledged mode for dedicated channels.

In acknowledged mode, retransmissions are undertaken in case of detected transmission errors not recovered by forward error control. This is also called automatic repeat  
15 request, ARQ. With ARQ, retransmissions can be undertaken unless a transmitted message is (positively) acknowledged. Retransmissions could also be initiated at explicit negative acknowledgments of transmitted messages. Generally  
20 there are time limits for the respective positive and negative acknowledgements to be considered.

Within this patent application, a radio network controller, RNC, is understood as a network element including a radio resource controller. Node B is a logical node responsible  
25 for radio transmission/reception in one or more cells to/from a User Equipment. A base station, BS, is a physical entity representing Node B.

Medium access control, MAC, and radio link control, RLC, is used within radio communications systems like General Packet Radio Services, GPRS, and UMTS.

5 U.S. Patent US5570367 discloses a wireless communications system arranged to transmit acknowledgement and request for retransmission messages. Data received in a microcell from an end user device is forwarded to a cell site. Data received by the cell site is transmitted to a cellular switch. A base station sends a poll message to the end  
10 user device, inquiring for the status of unacknowledged messages previously transmitted from the base station.

Also, a base station transmitter window is defined. A lower end pointer identifies a lowest numbered packet transmitted to and acknowledged by the base station. The  
15 upper end pointer identifies the highest numbered packet transmitted by the base station. Consequently, the window represents packets transmitted by the base station and unacknowledged by the end user device.

International Patent Application WO02096044 reveals a  
20 method and system of reducing or eliminating transmissions over a scarce communication link resource in a communications system by establishing an image of downlink transmissions status.

International Patent Application PCT/SE02/02186 includes a  
25 method and system for in-sequence delivery of RLC PDUs, transmitted in downlink direction, to a user equipment at handover.

3<sup>rd</sup> Generation Partnership Project (3GPP): Technical Specification Group Radio Access Network, Physical Layer Procedures, 3G TS 25.301 v3.6.0, France, September 2000, speci-  
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fies in chapter 5 Radio Interface Protocol Architecture of a UMTS system. There are three protocol layers:

- physical layer, layer 1 or L1,
- data link layer, layer 2 or L2, and
- 5       - network layer, layer 3 or L3.

Layer 2, L2, and layer 3, L3 are divided into Control and User Planes. Layer 2 consists of two sub-layers, RLC and MAC, for the Control Plane and four sub-layers, BMC, PDCP, RLC and MAC, for the User Plane. The acronyms BMC, PDCP, 10 RLC and MAC denote Broadcast/Multicast Control, Packet Data Convergence Protocol, Radio Link Control and Medium Access Control respectively.

Figure 1 illustrates a simplified UMTS layers 1 and 2 protocol structure for a Uu Stratum, UuS, or Radio Stratum, 15 between a user equipment UE and a Universal Terrestrial Radio Access Network, UTRAN.

Radio Access Bearers, RABs, make available radio resources (and services) to user applications. For each mobile station there may be one or several RABs. Data flows (in the 20 form of segments) from the RABs are passed to respective Radio Link Control, RLC, entities which amongst other tasks buffer the received data segments. There is one RLC entity for each RAB. In the RLC layer, RABs are mapped onto respective logical channels. A Medium Access Control, MAC, 25 entity receives data transmitted in the logical channels and further maps logical channels onto a set of transport channels. In accordance with subsection 5.3.1.2 of the 3GPP technical specification MAC should support service multiplexing e.g. for RLC services to be mapped on the same 30 transport channel. In this case identification of multi-

plexing is contained in the MAC protocol control information.

Transport channels are finally mapped to a single physical channel which has a total bandwidth allocated to it by the network. In frequency division duplex mode, a physical channel is defined by code, frequency and, in the uplink, relative phase (I/Q). In time division duplex mode a physical channel is defined by code, frequency, and time-slot. The DSCH (Downlink Shared Channel), e.g., is mapped onto one or several physical channels such that a specified part of the downlink resources is employed. As further described in subsection 5.2.2 of the 3GPP technical specification the L1 layer is responsible for error detection on transport channels and indication to higher layer, FEC encoding/decoding and interleaving/deinterleaving of transport channels..

PDCP provides mapping between Network PDUs (Protocol Data Units) of a network protocol, e.g. the Internet protocol, to an RLC entity. PDCP compresses and decompresses redundant Network PDU control information (header compression and decompression).

For transmissions on point-to-multipoint logical channels, BMC stores at UTRAN-side Broadcast Messages received from an RNC, calculates the required transmission rate and requests for the appropriate channel resources. It receives scheduling information from the RNC, and generates schedule messages. For transmission the messages are mapped on a point-to-multipoint logical channel. At the UE side, BMC evaluates the schedule messages and deliver Broadcast Messages to upper layer in the UE.

3G TS 25.301 also describes protocol termination, i.e. in which node of the UTRAN the radio interface protocols are

terminated, or equivalently, where within UTRAN the respective protocol services are accessible.

3<sup>rd</sup> Generation Partnership Project (3GPP): *Technical Specification Group Radio Access Network, Physical Layer Procedures*, 3G TS 25.322 v3.5.0, France, December 2000, specifies the RLC protocol. The RLC layer provides three services to the higher layers:

- transparent data transfer service,
- unacknowledged data transfer service, and
- 10       - acknowledged data transfer service.

In subsection 4.2.1.3 an acknowledged mode entity, AM-entity, is described (see figure 4.4 of the 3GPP Technical Specification). In acknowledged mode automatic repeat request, ARQ, is used. The RLC sub-layer provides ARQ functionality closely coupled with the radio transmission technique used. The 3GPP technical specification also reveals various triggers for a status report to be transmitted. The receiver shall always send a status report, if it receives a polling request. There are also three status report triggers, which can be configured

1. Missing PU(s) Detected,
2. Timer Initiated Status Report, and
3. Estimated PDU Counter.

For trigger 1, the receiver shall trigger transmission of a status report to the sender if a payload unit, PU, is detected to be missing. (One PU is included in one RLC PDU.) With trigger 2, a receiver triggers transmission of a status report periodically according to a timer. Finally, trigger 3 relates in short to a timer corresponding to an estimated number of received PUs before the requested PUs

are received. The 3GPP Technical Specification specifies a status PDU used to report the status between two RLC AM ('Acknowledged Mode') entities.

3<sup>rd</sup> Generation Partnership Project (3GPP): *Technical Specification Group Radio Access Network, High Speed Downlink Packet Access (HSDPA), Overall Description, 3G TS 25.308 v5.3.0, France, December 2002*, describes the overall support of High Speed Downlink Packet Access in UTRA. Figures 5.1-1 and 5.1-2 illustrate protocol architecture of HS-DSCH. Chapter 6 specifies HS-DSCH MAC architecture for the downlink.

3<sup>rd</sup> Generation Partnership Project (3GPP): *Technical Specification Group Radio Access Network, UTRAN Overall Description, 3G TS 25.401 v4.5.0, France, September 2002*, describes the overall architecture of UTRAN, including internal interfaces and assumptions on radio and Iu interfaces. Section 11.2.5 presents the DSCH Transport channel. DSCH scheduling is performed by MAC-c/sh in the CRNC.

3<sup>rd</sup> Generation Partnership Project (3GPP): *Technical Specification Group Radio Access Network, Physical layer aspects of UTRA High Speed Downlink Packet Access, 3G TS 25.848 v4.0.0, France, March 2001*, describes, among other things, physical layer aspect of the techniques behind the concept of high-speed downlink packet access (HSDPA). Section 6.3.1 presents a complexity analysis of a dual channel stop-and-wait protocol for downlink hybrid ARQ.

3<sup>rd</sup> Generation Partnership Project (3GPP): *Technical Specification Group Radio Access Network, Physical layer aspects of UTRA High Speed Downlink Packet Access, 3G TS 25.950 v4.0.0, France, March 2001*, describes several techniques for facilitating high-speed downlink packet access. Chap-

ter 8 describes various properties of stop-and-wait hybrid ARQ.

None of the cited documents above discloses a method and system of reducing uplink retransmission delay of a radio communications system by introducing an uplink MAC ARQ layer of Node B. Further, none of the cited documents mentions a MAC PDU data indicator for soft combining control in Node B.

#### SUMMARY OF THE INVENTION

10 Cited prior art references describe retransmissions between a UE and an RNC. According to preferred embodiments of the invention, transmissions and retransmissions are partially terminated in Node B, rendering soft combining of subsequent transmissions possible. Corresponding acknowledgements (positive or negative), if any, are terminated in UE.

Current WCDMA uplink connections has a latency in an approximate range of 100-150 ms. This latency is of such an amount that for some humans it is considered annoying, e.g., when using interactive services over the connection.

20 Further, present WCDMA releases provide wide area coverage for uplink data rates of 384 kbps. Applications proposed or recently presented require high peak rates in the uplink.

Consequently, it is an object to reduce transmission delay and latency over a scarce resource such as a radio interface.

25 A further object is to generate ARQ status reports in Node B and to render possible soft combining of subsequent (re-)transmissions.

It is also an object to segment RLC PDUs into MAC PDUs suitable for transmission in one transmission time interval, that may be shorter than allowed transmission time intervals of present WCDMA releases.

- 5 Finally, it is an object to introduce a reordering entity of RNC, handling RLC-PDUs received out of order, for improved out-of-order handling at RNC.

These objects are met by the invention, which is particularly well suited for a high-speed uplink packet access  
10 channel of an evolved universal mobile telecommunications system.

Preferred embodiments of the invention, by way of examples, are described with reference to the accompanying drawings below.

## 15 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 displays a layered protocol structure, according to prior art, in a radio communications system.

Figure 2 displays a layered protocol structure, according to the invention, in a radio communication system.

- 20 Figure 3 shows communication, according to the invention, between a UE and a base station involved in a connection between an RNC and the UE.

Figure 4 schematically illustrates MAC and RLC protocol layers, according to the invention, in a multilayer proto-  
25 col structure.

Figure 5 gives an overview of the uplink protocol structure according to a preferred embodiment of the invention.



Figure 6 shows a MAC PDU according to the preferred embodiment of the invention.

Figure 7 illustrates transmission of data and associated control fields on separate channels, according to the invention.

Figure 8 illustrates N time multiplexed channels for N channel stop-and-wait according to the preferred embodiment of the invention.

Figure 9 displays an RNC according to the invention.

Figure 10 displays a Node B according to the invention.

Figure 11 displays a User Equipment according to the invention.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 2 shows a preferred layered protocol structure, a protocol stack, according to the invention. The L2 MAC layer of figure 1 has been extended and divided into two sub-layers, a new L2 MAC sub-layer and a new MAC-ARQ sub-layer. Essentially the new L2 MAC sub-layer corresponds to the prior art L2 MAC sub-layer of figure 1. The MAC-ARQ plus the MAC layer could be regarded as one single MAC layer extended to also include hybrid ARQ functionality. However, for reasons of explanation they are preferably regarded as separate sub-layers. Further, on the network side, considering them as separate protocol sub-layers physically better corresponds to the physical entities where they reside. As illustrated in figure 2 on the UTRAN-side (or network side) L2 MAC sub-layer is preferably located in RNC, whereas L2 MAC-ARQ sub-layer is located in Node B. Hybrid ARQ protocol combine successively received retransmissions. It is a great advantage to have the hy-

brid ARQ protocol close to the physical layer and, particularly, in Node B. Among the advantages achieved thereby, e.g., the roundtrip delay is reduced as compared to a location in RNC. Within this patent application the protocol  
5 layers, except for L2 MAC and L2 MAC-ARQ as just explained, correspond to those of figure 1.

With reference to figure 3, Node B 1 and Node B 2 of a radio communications system are logical nodes responsible for radio transmission/reception in one or more cells to/from  
10 the User Equipment UE. BS 1 and BS 2 are physical entities representing Node B 1 and Node B 2 respectively. Node B 1 and Node B 2 terminate the air interface, called Uu interface within UMTS, between UE and respective Node B towards the radio network controller RNC. In UMTS the interface  
15 between a Node B and an RNC is called Iub interface.

Preferably, all Nodes B of the radio communications system operate according to the invention for outstanding performance. However, the invention can also be used in systems also including Nodes B not operating according to the in-  
20 vention.

Figure 4 describes somewhat more detailed than figure 2 the information transfer between the sub-layers of the protocol stack. In an exemplary situation, and with reference to figure 3, UE communicates over a radio link associated with  
25 BS 1. Packet switched data is transmitted in protocol data units, PDUs, in both directions. Each PDU is transported on a transport channel in at least one transport block, TB, as shown in figure 4. Preferably there is one TB for each PDU. As described above, transmission errors on the trans-  
30 port channel are corrected and detected by layer L1. Each transport block, TB, in figure 4 can be provided an individual CRC error-detecting checksum prior to transmission

on the physical channel. However, preferably a transmission unit, carrying one or more TBs, is provided only one CRC error-detecting checksum. If a transmission unit is detected to be in error on the receiving side, this is reported to the L2 MAC layer.

L2 MAC layer can request retransmission of transmission units received in error. Transmission units, detected to be in error, still carry information that should not be wasted. Preferably hybrid ARQ, utilizing information available from earlier transmission(s) of a transmission unit by proper combining with the latest retransmission, is used prior to an L2 MAC layer request for retransmission.

It is preferred that the Hybrid ARQ is terminated in Node B. Given L2 RLC located in RNC, the RLC layer should not be responsible of Hybrid ARQ. According to preferred embodiments of the invention, an L2 MAC-ARQ sub-layer is responsible of Hybrid ARQ. At UTRAN-side the L2 MAC-ARQ sub-layer is located in Node B.

One reason for terminating the Hybrid ARQ in Node B is the reduction of roundtrip delay as compared to terminating it in RNC. Another reason is that Node B is capable of using soft combining of multiply transmitted data packets, whereas RNC generally only receives hard-quantized bits.

At the receiving end, error detection is also performed by layer L2 RLC of figure 4. If an RLC protocol data unit, PDU, is received in error or the PDU is missing, it will be requested for retransmission at a point in time when a status report is established by the RLC layer. RLC PDUs are transferred to/from the MAC layer SDUs. The MAC SDU (Service Data Unit) possibly includes a header not included in the RLC PDU. As explained in relation to figure 2, according to the invention there are preferably two UTRAN MAC

sub-layers, an L2 MAC sub-layer and an L2 MAC-ARQ sub-layer. In a preferred embodiment of the invention, the L2 MAC sub-layer is located in RNC and the L2 MAC-ARQ sub-layer is located in Node B. As previously described, the RLC PDUs are transferred in transport blocks, TBs, on the physical channel. In the uplink direction the L2 MAC-ARQ layer transfers TBs, possibly after combining of multiple (re-)transmissions of the respective TBs, indicated to be error-free to the L2 MAC layer.

A network layer PDU or L3 PDU can comprise several RLC PDUs, as illustrated in figure 4. RLC PDUs are reassembled into RLC service data units, RLC SDU, prior to delivery to higher layer PDU. The L3 protocol can be, e.g., the Internet Protocol, IP. Upon reception from L3, RLC SDUs are segmented into RLC PDUs.

Figure 5 gives an overview of the uplink protocol structure according to the preferred embodiment of the invention. «RNC», «Node B 1», «Node B 2» and «UE» have been described in relation to figure 3. «MAC-ARQ 1» and «MAC-ARQ 2» are MAC-ARQ protocol layers according to the invention of Nodes B «Node B 1» and «Node B 2» respectively. In User Equipment «UE», an integer number of RLC PDUs «1», «2», ..., «i» are segmented into a MAC-layer PDU «MAC PDU» adapted for uplink transmission in one transmission time interval, TTI. Preferably, uplink transmissions are performed on an enhanced uplink channel with transmission time intervals shorter than transmission time intervals of prior art. Each Node B «Node B 1», «Node B 2» (positively) acknowledges «ARQ Status» successfully received MAC PDUs. Optionally, it may negatively acknowledge «ARQ Status» unsuccessfully received MAC PDUs. The acknowledgements are transmitted in downlink direction to User Equipment «UE». With only positive acknowledgements, if no acknowledgement

is received within a predetermined time, «UE» retransmits the unacknowledged MAC PDU, otherwise «UE» cancels the MAC PDU from buffer storing not yet acknowledged MAC PDUs. With optional negative acknowledgements the predetermined  
5 time period becomes less critical. However, due to the risk of misinterpreting a negative acknowledgement as a positive acknowledgment, channel dependent probability of such misinterpretation needs to be considered for various channel environments for an optimum selection.

10 MAC PDUs received by respective MAC-ARQ protocol layer «MAC-ARQ 1», «MAC-ARQ 2» of Nodes B «Node B 1», «Node B 2» are delivered to Radio Network Controller «RNC», which re-  
orders received MAC PDUs into sequential order. This is needed as, e.g., a single Node B may obtain successfully  
15 transmitted and received MAC PDUs out of order due to varying number of required retransmissions of different PDUs. Another exemplary reason is that at handover involving a plurality of Nodes B, different MAC PDUs of an RLC PDU are received and (re-)transmitted to RNC at different Nodes B  
20 for assembly in RNC, whereas for downlink transmissions there is only one transmitting entity (Node B) and one receiving entity (UE).

A reordering entity in radio network controller «RNC» provides in-sequence delivery of RLC PDUs «RLC PDUs», received  
25 in RNC, to RLC layer «RLC». Two alternative number sequences for reordering are considered:

- reordering based on RLC sequence numbers for both UM and AM RLC; or
- special sequence numbers on MAC level.

30 Special sequence numbers on MAC level is used for downlink HS-DSCH. However, if reordering is made in RNC number of

sequences can be reduced if reordering is based on RLC sequence numbers, keeping transmission overhead at a minimum.

The risk of receiving duplicate RLC PDUs also needs consideration. Elimination of duplicate RLC PDUs can be based on  
5 RLC sequence numbers as well. The elimination of duplicate RLC PDUs also reduces the negative impact of positive acknowledgements being received as negative acknowledgments in UE, if negative acknowledgments are made use of.

Preferably, hybrid ARQ is used, softly combining, if more  
10 than one, successive received (re-)transmissions of each MAC PDU. An identification of process identity «ProcessID» and an indicator of new data «NewData» in addition to payload «Payload» may either be included in data packets «MAC PDU» according to the HARQ protocol as indicated in figure  
15 6 or be handled separately but in association with payload data, illustrated in figure 7. The payload field «Payload» comprises an integer number of RLC PDUs. The indicator of new data «NewData» indicates whether or not a MAC PDU is a retransmission and is included for control of soft combining.  
20 This may be explicitly indicated, or indicated implicitly by a sequence number, which is increased for each transmission of a not earlier transmitted MAC PDU.

There is need for greater reliability at transmission of process identity and new data indicator fields «ProcessID»,  
25 «NewData», than payload. If control data is not received, corresponding payload cannot be soft-decision combined with data of other transmissions. Therefore, control fields «ProcessID» and «NewData» are transferred with higher reliability than the data channel transferring the payload.  
30 The higher reliability can be achieved by, e.g., more error resistant error control coding or increased transmission power. Preferably, control fields for process identity

«ProcessID» and new data indicator «NewData» are transmitted on a control channel separate from the data channel. The control and data channels are synchronized.

5 In addition to the control fields mentioned above there are control fields of nature well known in the art carrying information on, e.g., number of payload RLC PDUs and transport block size.

10 A well-known (one-channel) stop-and-wait ARQ protocol does not provide sufficient throughput for most studied relevant cases. According to the invention selective repeat or N-channel stop-and-wait ARQ is preferred.

For N-channel stop-and-wait, Node B needs to store soft samples of up to N different MAC PDUs for each UE. The N channels are time multiplexed as illustrated in figure 8.  
15 For a particular channel, no further data is transmitted until an acknowledgement is received or time for acknowledgement has elapsed according to a stop-and-wait protocol. I.e. acknowledgements are scheduled such that acknowledgement «1st ACK» acknowledging data transmitted in a 1<sup>st</sup>  
20 channel «1st channel» arrives not later than next transmission instant of 1<sup>st</sup> channel «1st channel». The same holds for 2<sup>nd</sup> channel «2nd channel» up to N<sup>th</sup> channel «Nth channel»

Figure 9 displays an RNC according to the invention. Receive means 1 receives first protocol data units, e.g. MAC  
25 PDUs, transferred from one or more Nodes B. Received first protocol data units are stored by buffering means 2. The first protocol data units are segmented into second protocol data units, e.g. RLC PDUs, by segmentation means 3. Reorder means 4 operates on the segmented buffered data  
30 units and reorders the second protocol data units as need be in consecutive order according to a sequence number. For transfer to higher layers, reassemble means 5 reassem-

bles the second protocol data units into service data units, which are transferred by transfer means 6.

The radio network further comprises processing means 7, verifying second protocol data units according to an error  
5 detecting code. Acknowledgments, preferably included in status reports, of second protocol data units are transmitted by transmit means 8.

Figure 10 displays a Node B according to the invention. Node B transmits responses to UE providing information on  
10 the outcome of data transfers over the radio interface from UE to Node B. In an example situation receive means 9 receive one or more first protocol data units, e.g. MAC PDUs, the received first protocol data units are stored in buffering means 10 and processed in protocol entity 11  
15 determining, among other things, whether the received data unit is valid codeword. Transmit means 12 accordingly acknowledges the received data unit to the sender (UE). When a multitude of transmissions are required for obtaining a valid received protocol data unit, the number  
20 of (re-)transmissions may be reduced by properly combining the transmissions. Optional combining means 13, performs such combining, preferably using soft decision information from the receive means 9.

Figure 11 displays a User Equipment, UE, according to the  
25 invention. Assemble means 14 assembles second protocol data units, e.g. RLC PDUs, to first protocol data units, e.g. MAC PDUs. The first protocol data units are buffered by buffering means 15 and transmitted one or more times, as  
30 need be, by transmit means 16. If transmission is considered successful according to, appeared or non-appeared, acknowledgements, positive or negative acknowledgements of first protocol data units are received by receive means 17.



Positive or negative acknowledgments of second protocol data units are received by receive means 18 optionally distinguishing from receive means 17.

5 A person skilled in the art readily understands that the receiver and transmitter properties of a BS or a UE are general in nature. The use of concepts such as BS, UE or RNC within this patent application is not intended to limit the invention only to devices associated with these acro-  
10 nyms. It concerns all devices operating correspondingly, or being obvious to adapt thereto by a person skilled in the art, in relation to the invention. As an explicit non-exclusive example the invention relates to mobile stations without a subscriber identity module, SIM, as well as user equipment including one or more SIMs. Further, protocols  
15 and layers are referred to in close relation with UMTS terminology. However, this does not exclude applicability of the invention in other systems with other protocols and layers of similar functionality.

20 The invention is not intended to be limited only to the embodiments described in detail above. Changes and modifications may be made without departing from the invention. It covers all modifications within the scope of the following claims.